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(54) Title: SMART ANTENNA BEAM ASSIGNMENT AT MOBILE STATION HAND-OFF

(57) Abstract

A cellular communications network includes a plurality of cells (112) whose base stations (114) have smart antenna capabilities. In connection with a potential mobile station (116) hand-off, the smart antenna capable base stations for the hand-off candidate cells report (228) not only on measured traffic channel verification signal strength, but also on measured direction of arrival azimuth orientation angle and/or identity of a particular one of the separate narrow beams which would be needed to serve that mobile station after hand-off. A particular one of the candidate cells is then selected (232) as the target cell for hand-off, and instructions (234, 236) concerning implementation of the hand-off are provided to that target cell. These hand-off implementation instructions include the direction/beam information previously supplied by that target cell. The particular one of the beams specified by the received direction/beam information is then activated (238) in the target cell and a hand-off of the mobile station to that cell is ordered (240).

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SMART ANTENNA BEAM ASSIGNMENT AT MOBILE STATION HAND-OFF

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application for patent is related to and incorporates by reference previously filed, commonly assigned, co-pending United States Application for Patent Serial No. 08/994,586, filed December 19, 1997, entitled "Method and System for Improving Handoffs in Cellular Mobile Radio Systems".

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to a cellular telephone network implementing a smart antenna technology at its base stations and, in particular, to the assignment of a proper smart antenna beam for target base station activation at mobile station hand-off.

Description of Related Art

It is well known in the art to utilize directive antennas in cellular communications networks. The most commonly recognized example of directive antenna use in cellular communications networks is based on the principle of sectorization, as is illustrated in FIGURE 1. A cell site 10 may comprise either one omnidirectional cell or a plurality, for example, three (or more), sector cells 12. Directive antennas 14, each with an appropriately selected beamwidth for the sector cell 12, are then utilized at each base station 16 to form a plurality of wide beams 18, one per sector cell, with the totality of the beams formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. In operation, each of the formed wide beams 18 is in continuous use to provide service within each corresponding sector cell 12.

Another example of directive antenna use in cellular communications networks is based on the use of smart antenna technology, as is illustrated in FIGURE 2A. Directive antennas 20 are utilized at each base station 16 of a cell site 10 to form a plurality of separate, perhaps slightly overlapping, narrow beams 22 within each sector cell 12, with the totality of the beams formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. In operation, and in contrast to the operation of the sectorized beams 18 of FIGURE 1, the narrow beams 22 are intermittently used only when necessary to provide service to one or more mobile stations 24, as is illustrated in FIGURE 2B. Put another way, in smart

antenna technology, the base station 16 controls its directive antenna 20 to activate at any given time only those individual ones of the plurality of separate, perhaps slightly overlapping, narrow beams 22 as are needed to serve active mobile stations 24 within the cell site 10.

Selection of the proper narrow beam 22 to serve a mobile station is a very important base station task. If an incorrectly oriented beam 22 is selected, there is a chance that communications with the mobile station will be lost. There is accordingly a need for a technique for proper smart antenna narrow beam 22 selection. More particularly, there is a need for such a technique for use at each instance of a mobile station hand-off (either intra-exchange or inter-exchange).

SUMMARY OF THE INVENTION

Prior to mobile station hand-off, the base station for each candidate cell makes and reports verification signal strength measurements with respect to the traffic channel currently being used by that mobile station. The base stations for the candidate cells which also have smart antenna capabilities further make a direction of arrival azimuth orientation angle determination with respect to that mobile station, and identify a particular one of the separate narrow beams which would be needed to serve that mobile station after hand-off. This direction/beam information is also reported with the signal strength measurements. Responsive to the verification signal strength measurement reports, a particular one of the candidate cells is selected as the target cell for hand-off. Instructions concerning implementation of the hand-off are then provided to that target cell. Furthermore, in the case where the target cell has a smart antenna capability, the hand-off implementation instructions also include the direction/beam information previously supplied by that cell. The base station for the target cell then activates the particular one of the beams specified by the received direction/beam information, and a hand-off of the mobile station to the target cell is ordered.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be acquired by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1, previously described, is a diagram of directive antenna beam coverage within a sectorized cell of a cellular communications network;

FIGURES 2A and 2B, previously described, are diagrams of directive antenna beam coverage within a smart antenna equipped cell of a cellular communications network;

FIGURE 3 is a cell diagram illustrating an exemplary cell configuration for a cellular communications network in which the present invention may be implemented;

FIGURES 4A and 4B are diagrams of directive antenna beam coverage within a combined sectorized/smart antenna cell of the present invention;

FIGURE 5 is a block diagram of a base station implementing the combined sectorized/smart antenna cell illustrated in FIGURES 4A and 4B;

FIGURES 6A-6B are a signal flow and network operation diagram illustrating operation of the network of FIGURE 3 to make a smart antenna beam assignment in connection with an inter-exchange hand-off of a mobile station; and

FIGURES 7A-7B are a signal flow and network operation diagram illustrating operation of the network of FIGURE 3 to make a smart antenna beam assignment in connection with an intra-exchange hand-off of a mobile station.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to FIGURE 3 wherein there is shown a cell diagram illustrating an exemplary cell site configuration for a cellular communications network 100 in which the present invention may be implemented. The cellular communications network 100 operates in accordance with one of a number of known air interface types including, for example, a digital time division multiple access (TDMA) protocol. In a digital TDMA cellular telephone network, for example, each cell site comprising either an omnidirectional cell, as shown for ease of illustration, or a sector cell, as shown in FIGURES 1 and 2A-2B (such omnidirectional and sector cells collectively identified herein as cell 112), operates with an assigned set of transmission frequencies selected from one or more of the available cellular communications authorized hyperbands (e.g., 800 MHZ, 1900 MHZ, and the like) and frequency bands (A, B, and the like) therein. The set of frequencies assigned to each cell 112 includes frequencies supporting both at least one control channel and a plurality of traffic channels, with the control and traffic channels operable in either or both an analog and/or a digital mode. Sets of assigned frequencies are different for adjacent cells 112, and such sets are not repeated for use by other cells except for those cells that are far enough away from each other to minimize the likelihood of adjacent or co-channel interference.

In the network 100, a base station 114 is provided for each of the cells 112. The base stations 114 engage in simultaneous communications with plural mobile

stations 116 operating roughly within the area of the associated cell 112. The control channel assigned to each cell 112 is used to carry system control signals between the base station 114 and proximately located mobile stations 116, and also to assist in the network with mobile station cell reselection. Such control signals include call originations, page signals, page response signals, location registration signals, traffic channel assignments, maintenance instructions, and cell selection or re-selection instructions. The traffic channels provided in each cell 112 are used to carry subscriber voice or data communications between the base station 114 and proximately located mobile stations 116 and also to assist in the hand-off operation.

The base stations 114 are illustrated as being positioned at or near the center of each of the cells 112. However, depending on geography and other known factors, the base stations 114 may instead be located at or near the periphery of, or otherwise away from the centers of, each of the cells. Each one of the base stations 114 includes a transmitter, a receiver, and a base station controller (none shown) connected to one or more directive antennae (also not shown) in a manner and with a configuration well known in the art.

The base stations 114 further communicate via signaling links and voice trunks 122 with a central control station, commonly referred to as a mobile switching center 118, which functions to control operation of the network 100. A boundary 134 is shown in bold in FIGURE 3 to differentiate between those cells 112 (collected in area 132(1)) served by a first mobile switching center 118(1), and those cells (collected in area 132(2)) serviced by a second mobile switching center 118(2). The mobile switching centers 118 are interconnected with each other and to the public switched telephone network (PSTN) 120 by signaling links and voice trunks 124. The mobile switching centers 118 operate to selectively connect subscriber voice and data communications to the mobile stations 116 through its base stations 114. Thus, the mobile switching center 118 controls system operation through and in response to the transmission of signals over the control channels to set-up on the traffic channels calls that are either originated by or terminated at the mobile stations 116. The mobile switching center 118 further controls, through and in response to traffic channel signals, the hand-off of a subscriber communication from a traffic channel of one cell 112 to a traffic channel of another cell as the subscriber mobile station 116 roams throughout the cellular service area during an ongoing communication.

Reference is now made to FIGURE 4A wherein there is shown a diagram of directive antenna beam coverage within a combined sectorized/smart antenna cell 112 of the present invention. A base station 114 for the cell 112 includes a first plurality of directive (sector) antennas 154 each operable to form a wide beam 156 for each

sector 158, with the totality of the sector coverage formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. The base station 114 for the cell 112 further includes a second plurality of directive (smart) antennas 160, one for each sector. Each of the second plurality of directive (smart) antennas 160 is operable to form a plurality of separate, perhaps slightly overlapping, narrow beams 162 (either switched or steerable) within each sector 158, with the totality of the smart beams formed thereby providing substantially omni-directional radio frequency coverage throughout the cell site area. For ease of illustration only one sector 158 is shown. It is further understood that only one physical directive antenna (comprising, for example, an antenna array) may be needed to implement the logical first and second directive antennas 154 and 160 in a particular sector. In operation, each of the wide beams 156 formed by the first directive antennas 154 is in continuous use to provide service within each corresponding sector 158 to mobile stations 116 present therein. With respect to the second directive antennas 160, however, only those narrow beams 162 which are needed to serve active mobile stations 116 therein are in use at a given time, as is illustrated in FIGURE 4B.

Reference is now made to FIGURE 5 wherein there is shown a block diagram of a base station 114 implementing the combined sectorized/smart antenna cell illustrated in FIGURES 4A and 4B. Each base station 114 includes a plurality of transceivers (Tx/Rx) 164 which operate in either as digital or analog mode on a certain frequency assigned to the cell 112 where the base station is located. A first set 164(1) of one or more of these transceivers 164 (providing at least control and perhaps also traffic channels) are connected to the first plurality of directive (sector) antennas 154 supporting the sector beams 156 (see, FIGURES 4A and 4B). A second set 164(2) of a plurality of these transceivers 164 (most likely providing only traffic channels) are connected to the second plurality of directive (smart) antennas 160 supporting the smart antenna beams 162 (see, FIGURES 4A and 4B). Each base station 114 is connected to a mobile switching center (MSC) 118. This connection may be made either directly (as generally indicated at 168(1)) or through a base station controller (BSC) 170 (as generally indicated at 168(2)). The manner of operation of the mobile switching center 118, base station controller 170 and base stations 114 in a coordinated fashion to provide cellular telephone service to mobile stations is well known to those skilled in the art.

The base station 114 further includes a first location verification module (LVM1) 172 operable in connection with one or more of the first directive (sector) antennas 154 to make measurements on mobile station uplink communications. The location verification module 172 is provided with an order to make these

measurements. This order specifies a frequency on which the measurements are to made, a time slot within which the measurements are to be made, and a digital voice color code (DVCC) necessary to unambiguously identify the mobile station whose uplink communications are to be measured. Responsive to the received order, the location verification module 172 tunes to the proper frequency within the proper time slot, decodes the DVCC, and then makes the uplink measurements on certain metrics such as signal strength and signal quality. The measurements are then reported for subsequent evaluation in connection with system operation, such as, for example, hand-off determinations.

The base station 114 still further includes a second location verification module (LVM2) 174 operable in connection with one or more of the second directive (smart) antennas 160 to make measurements on mobile station uplink communications. The location verification module 174 is similarly provided with an order to make these measurements. This order specifies a frequency on which the measurements are to made, a time slot within which the measurements are to be made, and a digital voice color code (DVCC) necessary to unambiguously identify the mobile station whose uplink communications are to be measured. Responsive to the received order, the location verification module 174 tunes to the proper frequency within the proper time slot, decodes the DVCC, and then makes the uplink measurements on certain metrics such as signal strength and signal quality. The measurements are then reported for subsequent evaluation in connection with system operation, such as, for example, hand-off determinations. The measurements may also be processed by the second location verification module 174 to determine a direction of arrival (DOA) azimuth orientation angle θ (see, FIGURE 4A) with respect to the mobile station.

Although illustrated as having separate location verification modules for the first plurality of directive (sector) antennas 154 and the second plurality of directive (smart) antennas 160, it will of course be understood that only one location verification module is typically needed for most applications and it is preferably used in conjunction with, and connected to, one or more of the second directive (smart) antennas 160. It is also possible to utilize a single location verification module in connection with both the first plurality of directive (sector) antennas 154 and the second plurality of directive (smart) antennas 160.

The base station 114 still further includes a smart antenna controller 176. The smart antenna controller 176 operates responsive to a determined direction of arrival (DOA) azimuth orientation angle θ (see, FIGURE 4A) identification with respect to a certain mobile station 116, and then identifies a certain one of the plurality of separate, perhaps slightly overlapping, narrow beams 162 corresponding to that angle

for serving the mobile station. The smart antenna controller 176 then configures the second directive antenna 160 for operation to activate the identified beam 162 for handling communications with the mobile station 116 (see, FIGURE 4B).

Reference is now once again made to FIGURE 3. As the mobile stations 116 move within the service area of the network 100, instances arise where a mobile station passes between two cells 112 within a single area 132, or from one cell in a first area 132(1) to another cell in a second area 132(2). In moving between the cells 112, the mobile stations 116, in conjunction with base station 114 collected information and also orders exchanged with and between the mobile switching centers 118, have an opportunity through hand-off to change the base station through which cellular radio communications are being effectuated. For example, a mobile station 116(1) is shown moving in the direction of arrow 126(1) between two cells 112 from area 132(1) into area 132(2). Here, an inter-exchange hand-off must occur in order to continue providing call service to the mobile station 116(1). As another example, a mobile station 116(2) is shown moving in the direction of arrow 126(2) between two cells 112 within the same area 132. Here, an intra-exchange hand-off must occur in order to continue providing call service to the mobile station.

Reference is now additionally made to FIGURES 6A-6B and 7A-7B wherein there is shown a signal flow and network operation diagram illustrating network operation to make a smart antenna beam assignment in connection with a hand-off of a mobile station. More particularly, FIGURES 6A-6B address the scenario wherein the hand-off (inter-exchange) is made from a cell 112(1) within a first area 132(1) generally towards cell 112(2) within a second area 132(2), and FIGURES 7A-7B address the scenario wherein the hand-off (intra-exchange) is made from a cell 112(4) generally towards cell 112(2) within the same area 132(2).

Turning first to FIGURES 6A-6B, the mobile station 116(1) is currently engaged in a call 200. The mobile station 116(1), operating if capable in accordance with known mobile assisted hand-off (MAHO) principles, periodically makes downlink signal strength measurements 202 on the traffic channel (of cell 112(1)) that is currently being used, and also periodically makes downlink signal strength measurements 204 on the control (i.e., measurement) channels of network identified cells 112, including cells 112(2) and 112(3), which neighbor the cell 112(1). These signal strength measurements are reported 206 to the base station 114(1) for the currently serving cell 112(1). The base station 114(1) concurrently makes uplink signal strength measurements 208 on the traffic channel that is currently being used by the mobile station 116(1).

The base station 114(1) processes the mobile station 116(1) reported 206 downlink signal strength measurements (202 and 204), if available, and the base station made uplink signal strength measurements (208) to determine first whether a hand-off is necessary (action 210) and second, if yes, to which candidate cells the hand-off could and/or should preferably occur (action 212). In this example, it is assumed that the base station 114(1) determines 210 from deteriorating measured uplink and/or downlink signal strengths that a hand-off is necessary. It is further assumed that an identification 212 is made of a plurality of candidate cells 112 for hand-off. These candidate cells 112 may include cells in the same first area 132(1) as the current cell 112(1) such as cell 112(3), as well as cells in other areas 132, such as cell 112(2) in second area 132(2). It will, of course, be understood that the decision to hand-off may instead be made by the mobile station 116(1) itself. A request 214 for hand-off including information comprising an identification of the currently serving cell 112(1), the traffic channel being used for communication with mobile station 116(1) in cell 112(1), the time slot (for a digital traffic channel) carrying the cellular communication, the digital voice color code (DVCC), and the list of potential candidate cells 112 for hand-off, is then sent by the base station 114(1) to the serving mobile switching center 118(1).

With respect to inter-exchange signaling and a potential for inter-exchange hand-off, the currently serving mobile switching center 118(1) signals 218 the cooperating mobile switching center 118(2) requesting verification of connected base station 114 communications capability with the mobile station 116(1) (i.e., a hand-off measurement request). The signal 218, like the request 214 sent by the base station 114(1), includes information comprising an identification of the currently serving cell 112(1), the traffic channel being used for communication with mobile station 116(1) in cell 112(1), the time slot (for a digital traffic channel) carrying the cellular communication, and the digital voice color code (DVCC).

Responsive to receipt of the signal 218, the cooperating mobile switching center 118, such as mobile switching center 118(2), determines in action 220 from the identification of the cell 112(1), which of its served cells, such as cell 112(2), are neighbors (i.e., candidate cells) for hand-off. As an alternative, this neighbor/candidate list may be provided by the currently serving mobile switching center 118(1). The cooperating mobile switching center 118(2) then signals 222 the base station 114, such as base station 114(2), for each of its connected candidate cells, such as cell 112(2), to make a verifying signal strength measurement (action 224) on the traffic channel currently being used by the mobile station 116(1) in the currently serving cell 112(1). In connection with the making of this step 224 measurement, the

base station 114(2) further makes in step 226 a direction of arrival (DOA) azimuth orientation angle determination towards the mobile station 116(1) and further identifies which one of the plurality of separate, perhaps slightly overlapping, narrow beams 162 correspond with that angle and thus would be needed to serve the mobile station 116(1) within the cell 112(2).

Additionally, at or about the same time, the mobile switching center 118(1) has similarly identified in action 220 which of its connected cells 112 are neighbors (i.e., candidate cells) to cell 112(1) for hand-off. The mobile switching center 118(1) then similarly signals 222 the base station 114 for each of its connected candidate cells 112, such as the cell 112(3), to make a verifying signal strength measurement (action 224) on the traffic channel currently being used by the mobile station 116(1) in the currently serving cell 112(1). In connection with the making of this step 224 measurement, the base station 114(3) further makes in step 226 a direction of arrival azimuth orientation angle determination towards the mobile station 116(1) and further identifies which one of the plurality of separate, perhaps slightly overlapping, narrow beams 162 correspond with that angle and thus would be needed to serve the mobile station 116(1) within the cell 112(3).

Each base station 114 instructed by a received signal 222 then reports 228 the results of the verification signal strength measurement to their serving mobile switching center 118 (in, for example, a hand-off measurement report), along with an identification (if available) of both the direction of arrival azimuth orientation angle and the narrow beam 162 corresponding to that angle. In the case of reports 228 made to cooperating mobile switching centers 118, such as mobile switching center 118(2), the reported verification signal strength measurements (and additional smart antenna related information) are forwarded 230 on to the mobile switching center 118(1). The verification signal strength measurement results are then processed (action 232) by the mobile switching center 118(1) to determine which one of the candidate cells 112 comprises the best (i.e., the target) cell for hand-off of the call 200 based on the success and strength of the verification signal strength measurement.

Assuming now that the identified target cell for hand-off comprises the cell 112(2) in the area 132(2), the serving mobile switching center 118(1) requests from the target mobile switching center 118(2) assignment and reservation of a traffic channel (and time slot therein for a digital traffic channel) for hand-off of the call 200 in signal 234. This signal 234 includes an identification of both the direction of arrival azimuth orientation angle and the narrow beam 162 corresponding to that angle (that were provided in the step 228 report). The base station 114(2) and mobile switching center 118(1) are then informed 236 of the assignment by the mobile switching center

118(2) of the traffic channel in the target cell 112(2), the signal 236 to the base station 114(2) similarly including an identification of both the direction of arrival azimuth orientation angle and the narrow beam 162 corresponding to that angle (that were provided in the step 228 report) and forwarded in the signal 234. Responsive thereto, the base station 114(2) activates the proper narrow beam 162 in step 238 that is either identified and/or corresponds to the provided direction of arrival information. The mobile switching center 118(1) then signals 240 the mobile station 116(1) via the base station 114(1) for the currently serving cell 112(1) with a handover command directing the mobile station to switch to the assigned traffic channel (and time slot therein if appropriate) in the target cell 112(2). The mobile station 116(1) then tunes to and accesses 242 the assigned traffic channel (in the proper time slot). When the base station 114(2) detects the mobile station access (action 244), the mobile switching center 118(1) is informed 246, and the call 200 is switched 248 to the mobile switching center 118(2) for further handling to complete the hand-off procedure.

Turning next to FIGURES 7A-7B, the mobile station 116(2) is currently engaged in a call 200. The mobile station 116(2), operating if capable in accordance with known mobile assisted hand-off (MAHO) principles, periodically makes downlink signal strength measurements 202 on the traffic channel (of cell 112(4)) that is currently being used, and also periodically makes downlink signal strength measurements 204 on the control (i.e., measurement) channels of network identified cells 112, including cells 112(2) and 112(1), which neighbor the cell 112(4). These signal strength measurements are reported 206 to the base station 114(4) for the currently serving cell 112(4). The base station 114(4) concurrently makes uplink signal strength measurements 208 on the traffic channel that is currently being used by the mobile station 116(2).

The base station 114(4) processes the mobile station 116(2) reported 206 downlink signal strength measurements (202 and 204), if available, and the base station made uplink signal strength measurements (208) to determine first whether a hand-off is necessary (action 210) and second, if yes, to which candidate cells the hand-off could and/or should preferably occur (action 212). In this example, it is assumed that the base station 114(4) determines 210 from deteriorating measured uplink and/or downlink signal strengths that a hand-off is necessary. It is further assumed that an identification 212 is made of a plurality of candidate cells 112 for hand-off. These candidate cells 112 may include cells in the same second area 132(2) as the current cell 112(4) such as cell 112(2), as well as cells in other areas 132, such as cell 112(1) in first area 132(1). It will, of course, be understood that the decision to hand-off may instead be made by the mobile station 116(2) itself. A request 214

for hand-off including information comprising an identification of the currently serving cell 112(4), the traffic channel being used for communication with mobile station 116(2) in cell 112(4), the time slot (for a digital traffic channel) carrying the cellular communication, the digital voice color code (DVCC), and the list of potential candidate cells 112 for hand-off, is then sent by the base station 114(4) to the serving mobile switching center 118(2).

Responsive to receipt of the signal 214, the serving mobile switching center 118(2), determines in action 220 from the identification of the cell 112(4), which of its served cells, such as cell 112(2), are neighbors (i.e., candidate cells) for hand-off. The serving mobile switching center 118(2) then signals 222 the base station 114, such as base station 114(2), for each of its connected candidate cells, such as cell 112(2), to make a verifying signal strength measurement (action 224) on the traffic channel currently being used by the mobile station 116 in the currently serving cell 112(4). In connection with the making of this step 224 measurement, the base station 114(2) further makes in step 226 a direction of arrival (DOA) azimuth orientation angle determination towards the mobile station 116(2) and further identifies which one of the plurality of separate, perhaps slightly overlapping, narrow beams 162 correspond with that angle and thus would be needed to serve the mobile station 116(2) within the cell 112(2).

Each base station 114 instructed by a received signal 222 then reports 228 the results of the verification signal strength measurement to their serving mobile switching center 118 (in, for example, a hand-off measurement report), along with an identification (if available) of both the direction of arrival azimuth orientation angle and the narrow beam 162 corresponding to that angle. The verification signal strength measurement results are then processed (action 232) by the mobile switching center 118(2) to determine which one of the candidate cells 112 comprises the best (i.e., the target) cell for hand-off of the call 200 based on the success and strength of the verification signal strength measurement.

Assuming now that the identified target cell for hand-off comprises the cell 112(2) in the area 132(2), the serving mobile switching center 118(2) assigns (and reserves) a traffic channel (and time slot therein for a digital traffic channel) for hand-off of the call 200. The base station 114(2) is then informed 254 of the assignment by the mobile switching center 118(2) of the traffic channel in the target cell 112(2), the signal 254 to the base station 114(2) including an identification of both the direction of arrival azimuth orientation angle and the narrow beam 162 corresponding to that angle (that were provided in the step 228 report). Responsive thereto, the base station 114(2) activates the proper narrow beam 162 in step 256 that is either identified and/or

corresponds to the provided direction of arrival information. The mobile switching center 118(2) then signals 258 the mobile station 116(2) via the base station 114(4) for the currently serving cell 112(4) with a handover command directing the mobile station to switch to the assigned traffic channel (and time slot therein if appropriate) in the target cell 112(2). The mobile station 116(2) then tunes to and accesses 260 the assigned traffic channel (in the proper time slot). When the base station 114(2) detects the mobile station access (action 262), the mobile switching center 118(2) is informed 264, and the call 200 is switched 266 to the base station 114(2) for further handling to complete the hand-off procedure.

As discussed above, certain smart antenna beam service information is communicated within the network to assist with effectuating an efficient hand-off. This information comprises measured direction of arrival data and/or smart antenna beam identification. In the context of inter-exchange hand-off, this smart antenna beam service information must be communicated between the exchanges. It is envisioned that such communications could be effectuated through new ANSI-41 messages, modifications to existing ANSI-41 messages, or the use of proprietary ANSI-41 extensions. Other inter-exchange messaging could also be specified for communication of this information. Still further, in the context of intra-exchange hand-off, this smart antenna beam service information could be communicated between the nodes of the system through new (standardized) network messages, modifications to existing (standardized) messages, of the use of proprietary messages. In general, the communication of smart antenna beam service information could be provided in any facilities invoking network transaction, within the hand-off context (including hand-off to third and hand-off back scenarios) as well as outside the hand-off context, where the information would be of benefit to efficiently invoking the network facilities and using the proper smart antenna beam in providing service to mobile stations.

Although preferred embodiments of the method and apparatus of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A method for operating a cellular communications network, comprising the steps of:

detecting with respect to a mobile station cellular call in a first cell a need to perform a hand-off;

identifying a plurality of second cells neighboring the first cell as potential candidates for receiving the hand-off, each second cell associated with a base station having smart antenna capability;

requesting that each second cell perform a verification signal strength measurement on the cellular call and determine smart antenna beam service related information with respect to the mobile station;

reporting second cell verification signal strength measurement results and smart antenna beam service related information;

processing of the reported second cell verification signal strength results to identify one of the second cells as a target for the hand-off;

instructing the mobile station and target one of the second cells to engage in the hand-off, the instruction to the target one of the second cells including its previously reported smart antenna beam service related information;

activating by the target one of the second cells a particular one of a plurality of smart antenna beams in accordance with the instructed smart antenna beam service related information; and

handing off of the cellular call to the target certain one of the second cells.

2. The method as in claim 1 wherein the first cell is served by a first mobile switching center and the target one of the second cells is served by a second mobile switching center:

wherein the step of reporting includes the step of reporting the second cell verification signal strength measurement results and smart antenna beam service related information from the second mobile switching center to the first mobile switching center; and

wherein the step of instructing comprises the step of issuing the instructing from the first mobile switching center to the second mobile switching center.

3. The method as in claim 2 wherein the hand-off comprises an inter-exchange hand-off.

4. The method as in claim 1 wherein the first cell and the target one of the second cells are both served by a same mobile switching center, and wherein the hand-off comprises an intra-exchange hand-off.

5. The method as in claim 1 wherein the smart antenna beam service related information determined by each second cell comprises a measured direction of arrival to the base station with respect to the mobile station.

6. The method as in claim 1 wherein the smart antenna beam service related information determined by each second cell comprises an identification of the particular one of the plurality of smart antenna beams to serve the mobile station, that beam having an orientation generally corresponding to a measured direction of arrival to the base station with respect to the mobile station.

7. A method for operating a cellular communications network, comprising the steps of:

detecting with respect to a mobile station cellular call in a first cell of a first exchange area a need to perform a hand-off;

processing information by the first exchange area concerning verification signal strength measurements made by a plurality of second cells of a second exchange area neighboring the first cell to identify one of the second cells as a target for hand-off of the cellular call, wherein each second cell is associated with a base station having smart antenna capability; and

issuing an order from the first exchange area to the second exchange area to engage in an inter-exchange hand-off of the cellular call to the target one of the second cells, the order including information indicative of a particular one of a plurality of smart antenna beams to be activated by the target one of the second cells in providing service to the mobile station after hand-off.

8. The method as in claim 7 wherein the information in the first exchange area issued order comprises a measured direction of arrival to the base station of the target one of the second cells with respect to the mobile station.

9. The method as in claim 7 wherein the information in the first exchange area issued order comprises an identification of the particular one of the plurality of smart antenna beams having an orientation generally corresponding to a measured

direction of arrival to the base station of the target one of the second cells with respect to the mobile station.

10. The method as in claim 7 further including the step of:

reporting from the second exchange area to the first exchange area with smart antenna beam service related information determined by each second cell that is indicative of the particular one of the plurality of smart antenna beams to be activated by that second cell in providing service to the mobile station after hand-off.

11. The method as in claim 10 wherein the step of issuing the order including the information comprises the step of returning the smart antenna beam service related information determined by the target one of the second cells back to that target cell.

12. The method as in claim 7 further including the step of:

reporting from the second exchange area to the first exchange area with smart antenna beam service related information determined by each second cell that is indicative of a measured direction of arrival to the base station of that second cell with respect to the mobile station.

13. A cellular communications network, comprising:

a first cell supporting a cellular call;

a plurality of second cells comprising neighboring cells of the first cell, each of the second cells associated with a base station supporting smart antenna capability;

wherein the base station for each second cell operates to:

measure and report verification signal strength of the mobile station cellular call; and

determine and report smart antenna beam service related information with respect to potentially supporting the mobile station cellular call after hand-off;

a control node operable responsive to the reported verification signal strength measurements to:

select one of the plurality of second cells as a target for hand-off of the cellular call; and

signal the mobile station and the target one of the second cells to engage in a hand-off, the instruction to the target one of the second cells

including its previously reported smart antenna beam service related information; and

wherein the base station for the target one of the second cells further operates responsive to the instruction to activate a particular one of a plurality of smart antenna beams in accordance with the smart antenna beam service related information to serve the mobile station following hand-off.

14. The network as in claim 13 further including:

a first mobile switching center serving the first cell; and

a second mobile switching center serving the plurality of second cells;

wherein the verification signal strength measurements and smart antenna beam service related information are reported from the second mobile switching center to the first mobile switching center; and

wherein the signal is issued from the first mobile switching center to the second mobile switching center.

15. The network as in claim 14 wherein the hand-off comprises an inter-exchange hand-off.

16. The network as in claim 13 further including:

a mobile switching center serving both the first cell and the plurality of second cells; and

wherein the hand-off comprises an intra-exchange hand-off.

17. The network as in claim 13 wherein the smart antenna beam service related information determined by each second cell comprises a measured direction of arrival to the base station with respect to the mobile station.

18. The network as in claim 13 wherein the smart antenna beam service related information determined by each second cell comprises an identification of the particular one of the plurality of smart antenna beams to serve the mobile station having an orientation generally corresponding to a measured direction of arrival to the base station with respect to the mobile station.

19. A cellular communications network, comprising:

a first base station for a first cell operating with respect to a mobile station cellular call currently being handled a need to perform a hand-off;

a second base station for a second cell neighboring the first cell, the second base station supporting smart antenna capability;

a processing node connected to the first and second base stations and operating to select the second cell as a target for the hand-off and issuing an order to engage in a hand-off of the cellular call to the target second cell, the order including information indicative of a particular one of a plurality of smart antenna beams to be activated by the second base station in providing service to the mobile station after hand-off.

20. The network as in claim 19 wherein the information in the issued order comprises a measured direction of arrival to the second base station of the target second cell with respect to the mobile station.

21. The network as in claim 19 wherein the information in the issued order comprises an identification of the particular one of the plurality of smart antenna beams having an orientation generally corresponding to a measured direction of arrival to the second base station of the target second cell with respect to the mobile station.

22. The network as in claim 19 further including:

a first mobile switching center serving the first base station; and

a second mobile switching center serving the second base station;

wherein the second base station is operable to determine smart antenna beam service related information with respect to the mobile station and report this information through the first mobile switching center to the first mobile switching center; and

wherein the order is issued from the first mobile switching center through the second mobile switching center to the second base station, and the included information comprises the previously reported smart antenna beam service related information.

23. The network as in claim 22 wherein the hand-off comprises an inter-exchange hand-off.

24. The network as in claim 19 further including:

a mobile switching center serving both the first cell and the plurality of second cells; and

wherein the second base station is operable to determine smart antenna beam service related information with respect to the mobile station and report this information through to the mobile switching center; and

wherein the order is issued from the mobile switching center to the second base station, and the included information comprises the previously reported smart antenna beam service related information.

25. The network as in claim 24 wherein the hand-off comprises an intra-exchange hand-off.

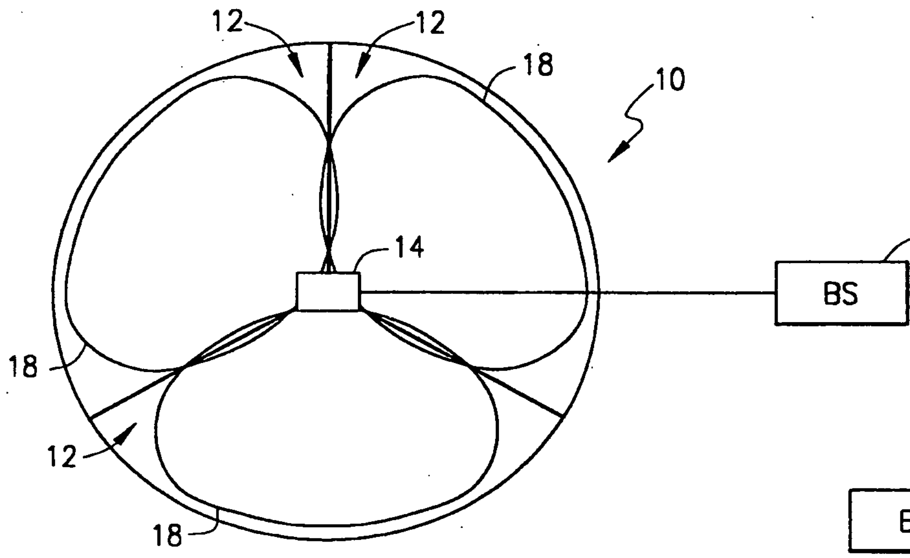


FIG. 1
(PRIOR ART)

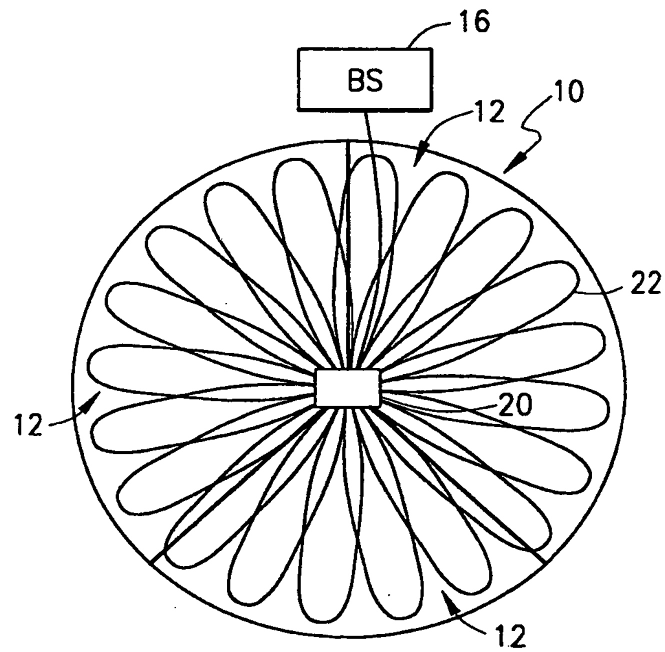


FIG. 2A
(PRIOR ART)

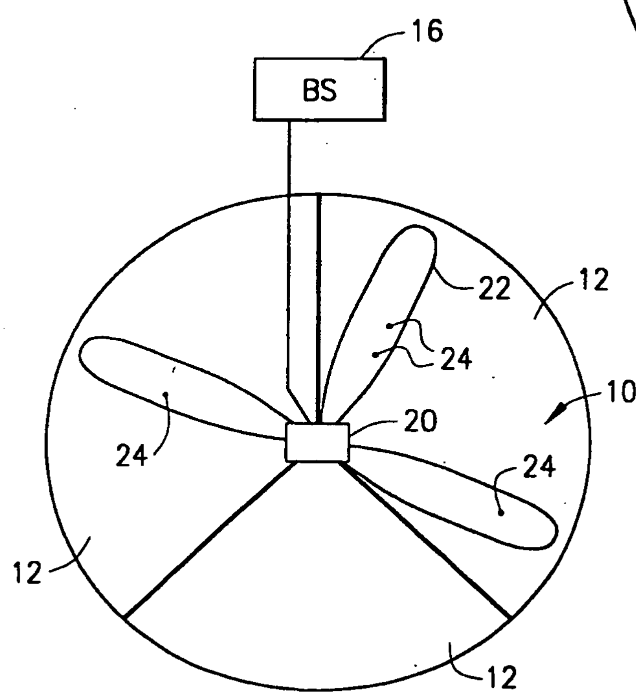


FIG. 2B
(PRIOR ART)

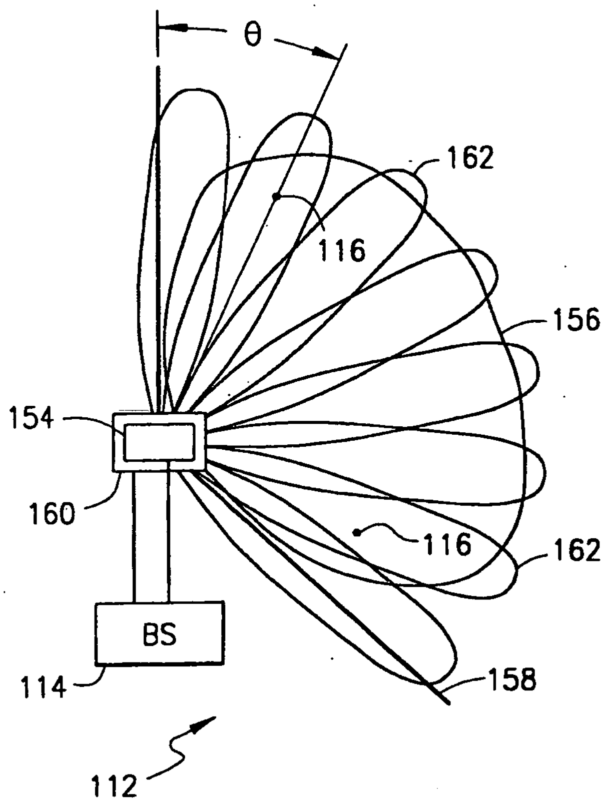

θ
162
116
156
154
160
116
162
BS
114
158
112

FIG. 4A

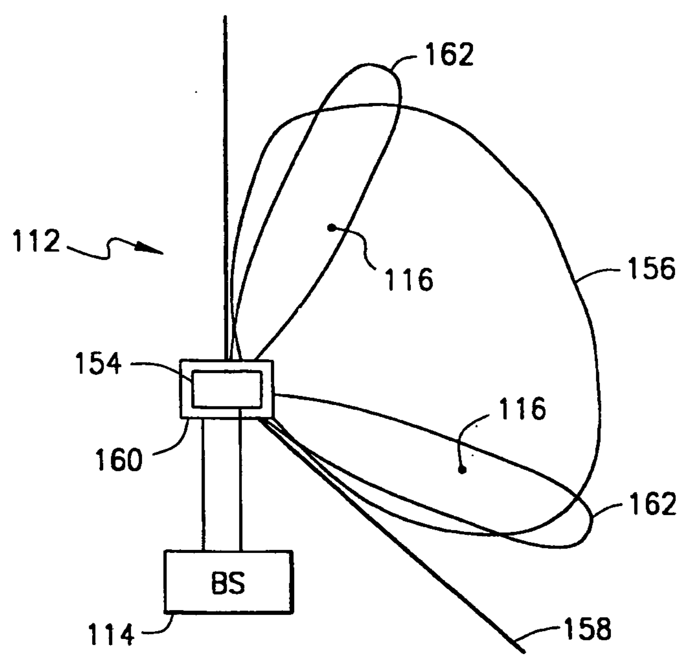

162
112
116
156
154
116
160
162
BS
114
158

FIG. 4B

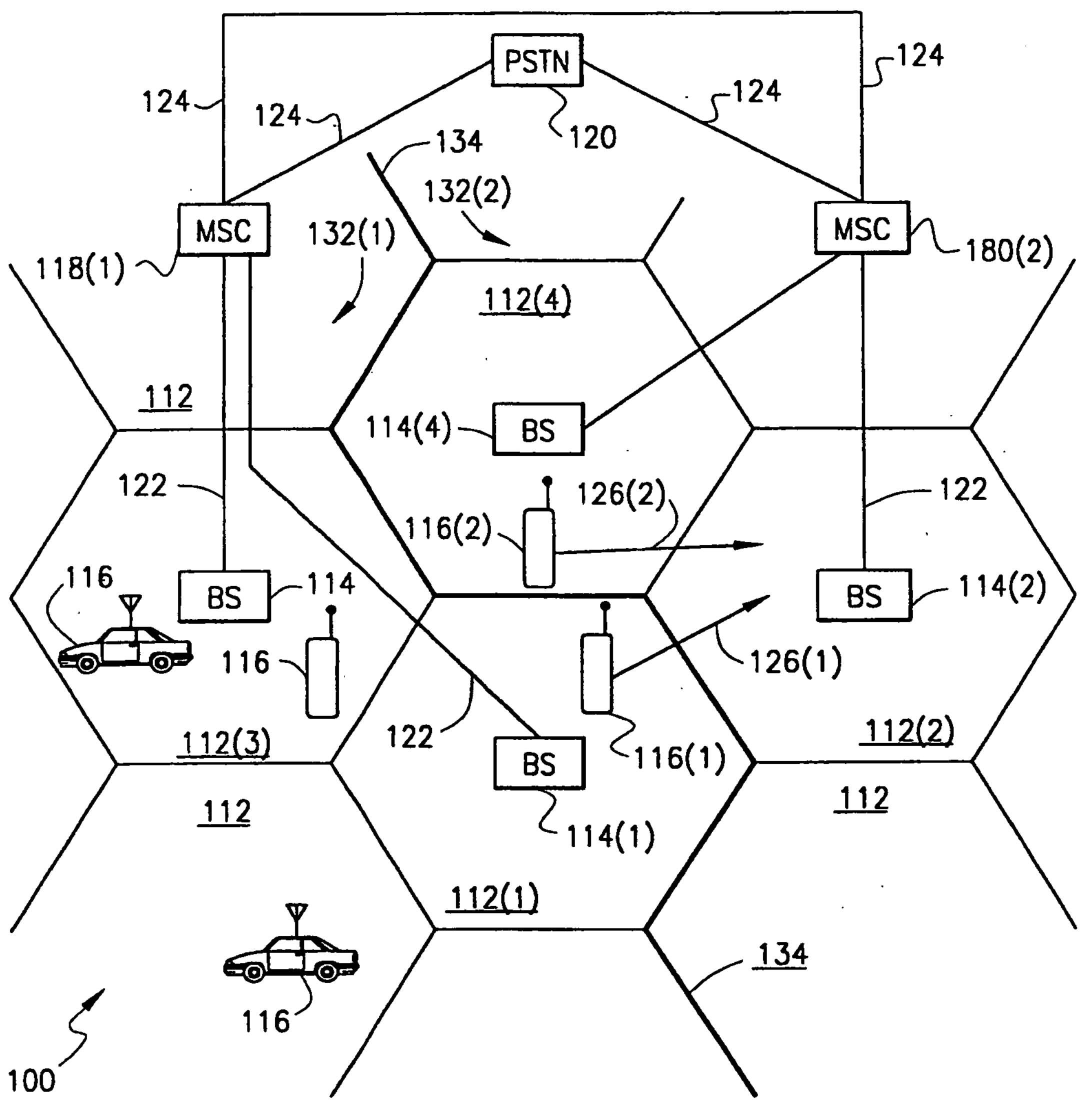

PSTN
120
124
124
124
124
134
132(2)
132(1)
MSC
118(1)
MSC
180(2)
112(4)
112
114(4)
BS
122
126(2)
116(2)
122
116
BS
114
BS
114(2)
116
126(1)
112(3)
122
BS
116(1)
112(2)
112
114(1)
112
112(1)
134
116
100

FIG. 3

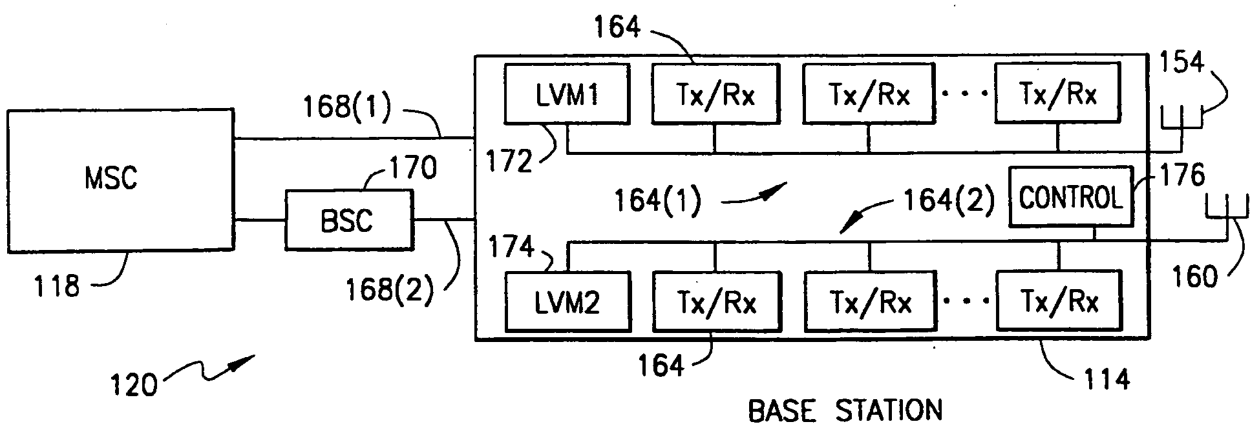

164
154
168(1)
LVM1
Tx/Rx
Tx/Rx
Tx/Rx
MSC
172
170
176
164(1)
164(2)
CONTROL
BSC
174
118
168(2)
LVM2
Tx/Rx
Tx/Rx
Tx/Rx
160
164
114
120
BASE STATION

FIG. 5

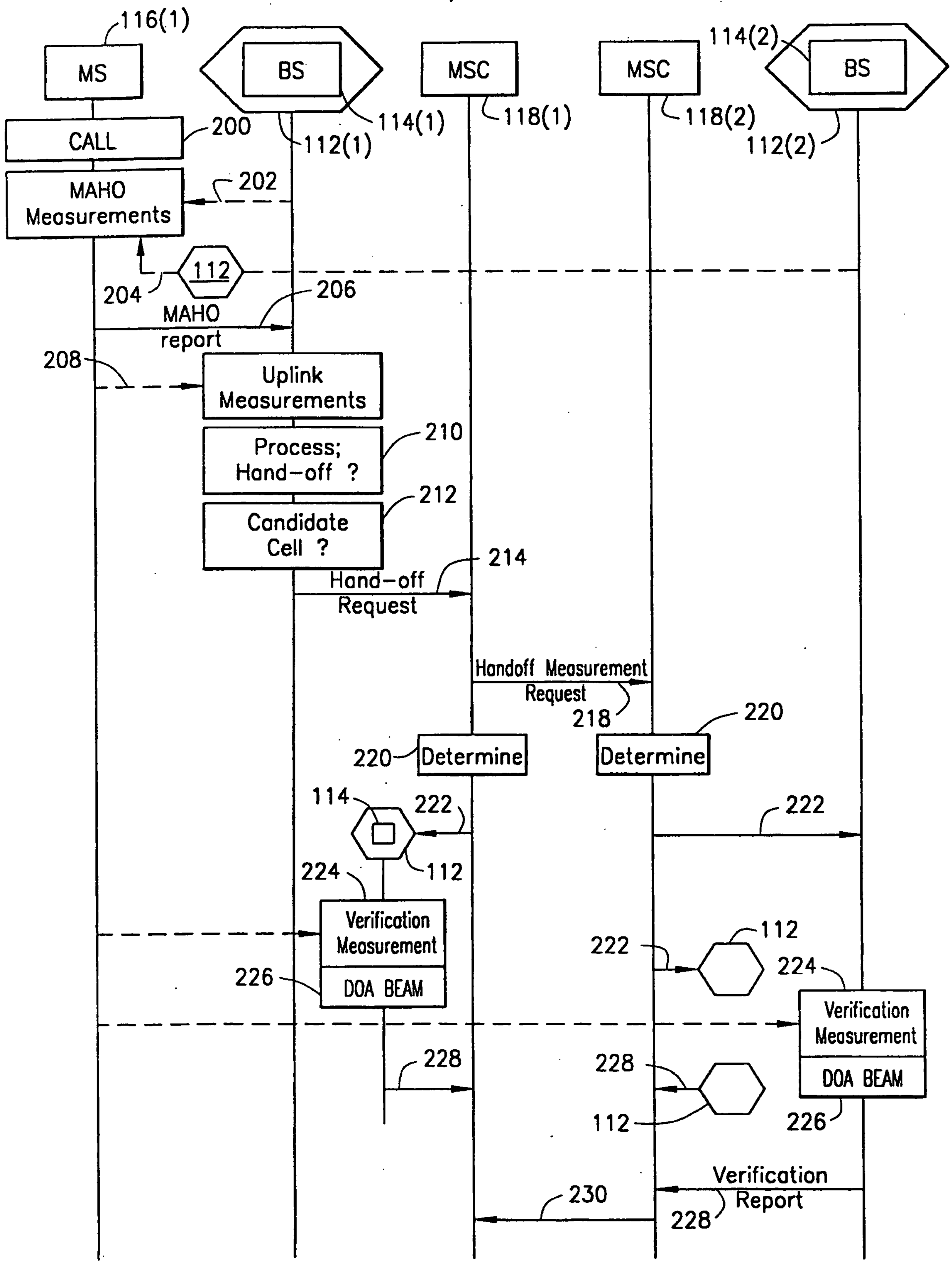
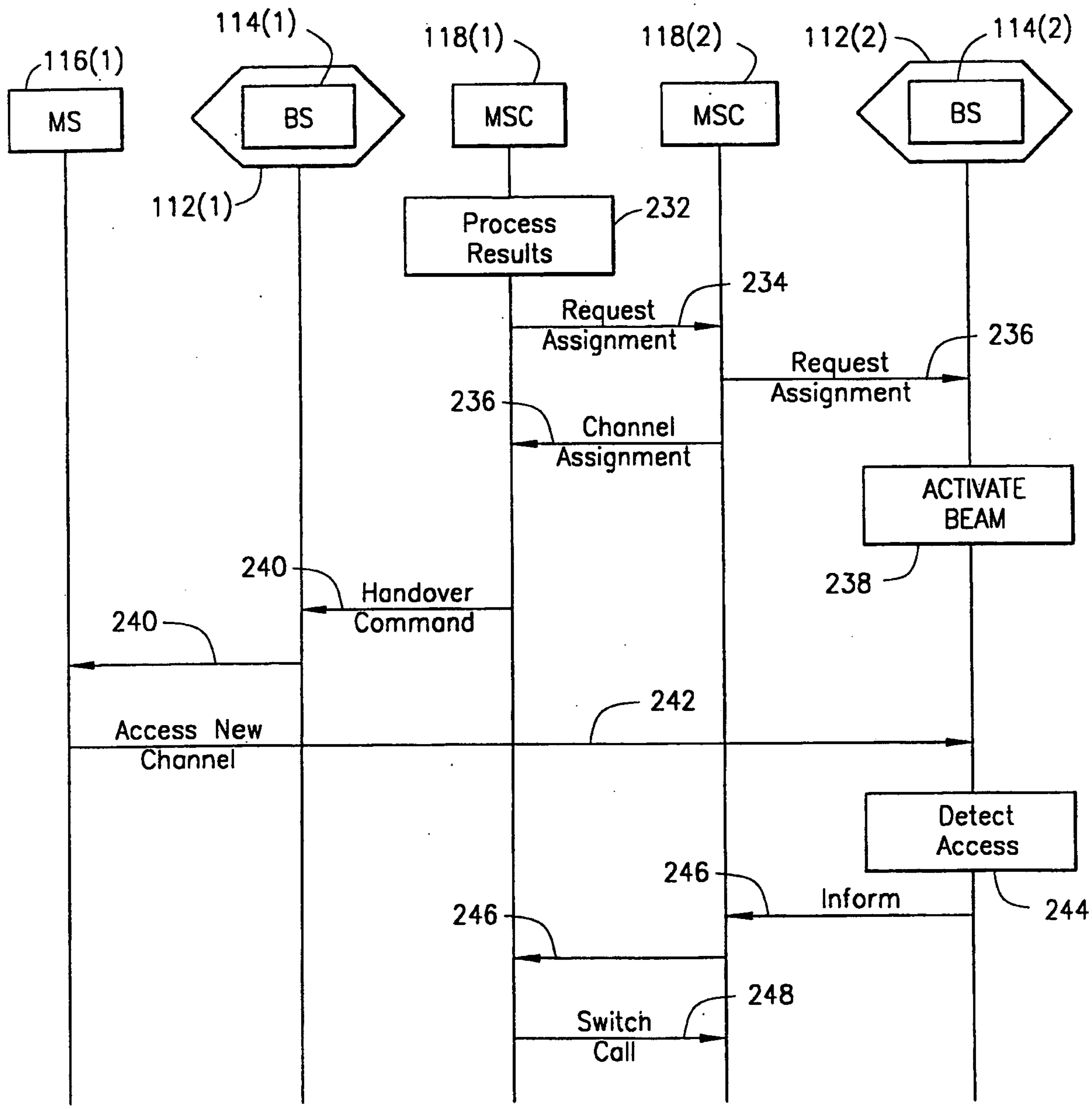

116(1)
MS
BS
MSC
MSC
114(2)
BS
114(1)
118(1)
118(2)
112(1)
112(2)
CALL
200
MAHO Measurements
202
112
204
206
MAHO report
208
Uplink Measurements
Process; Hand-off ?
210
Candidate Cell ?
212
214
Hand-off Request
Handoff Measurement Request
218
220
Determine
220
Determine
114
222
222
112
224
Verification Measurement
DOA BEAM
226
222
112
224
Verification Measurement
DOA BEAM
228
228
112
226
Verification Report
230
228

FIG. 6A



116(1)
MS
114(1)
BS
112(1)
118(1)
MSC
118(2)
MSC
112(2)
114(2)
BS
Process Results
232
Request Assignment
234
Request Assignment
236
236
Channel Assignment
ACTIVATE BEAM
238
240
Handover Command
240
242
Access New Channel
Detect Access
246
Inform
244
246
248
Switch Call

FIG. 6B

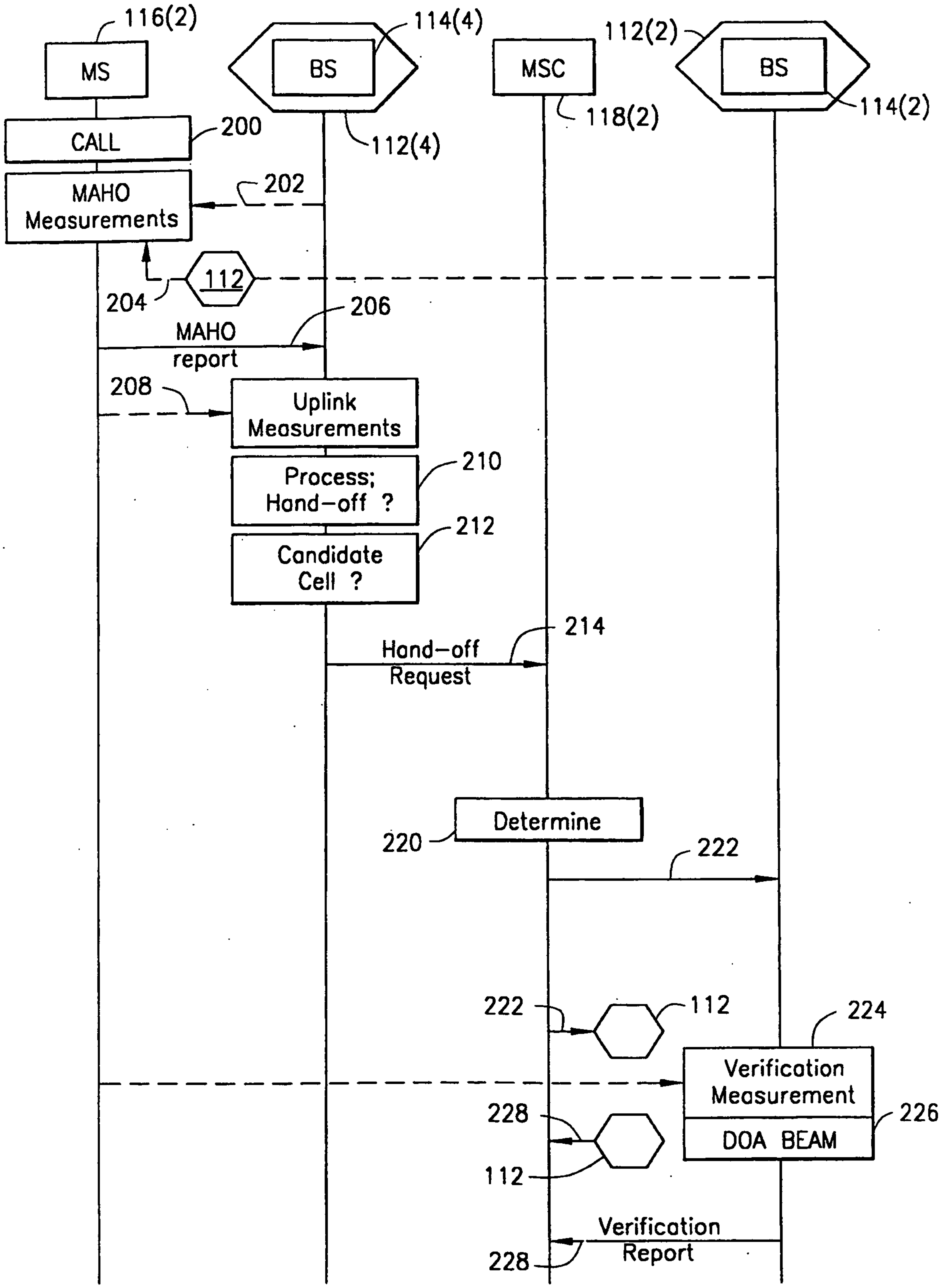

116(2)
MS
114(4)
BS
112(2)
MSC
BS
118(2)
114(2)
112(4)
CALL
200
MAHO
Measurements
202
112
204
206
MAHO
report
208
Uplink
Measurements
Process;
Hand-off ?
210
Candidate
Cell ?
212
214
Hand-off
Request
Determine
220
222
222
112
224
Verification
Measurement
DOA BEAM
226
228
112
Verification
Report
228

FIG. 7A

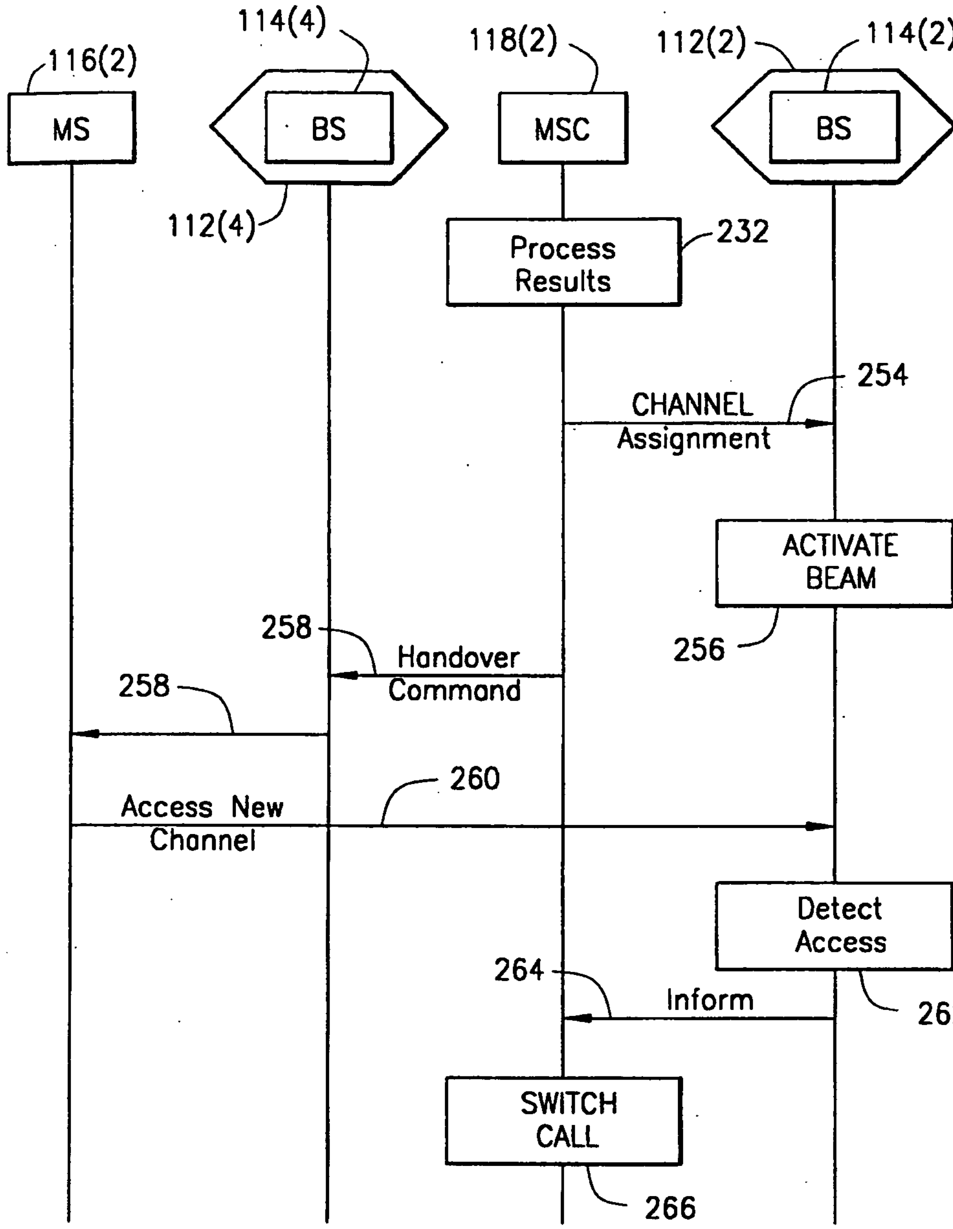

116(2)
MS
114(4)
BS
112(4)
118(2)
MSC
112(2)
114(2)
BS
Process Results
232
CHANNEL Assignment
254
ACTIVATE BEAM
256
258
Handover Command
258
Access New Channel
260
Detect Access
262
264
Inform
SWITCH CALL
266

FIG. 7B